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ONE HALF A REVOLUTION IN ORIENTATION

IMPLICATIONS FOR DECISION MAKING

by

Robert R. Allardice, Lt Col, USAF

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Advisor: Dr. William Martel & Col (Ret) Ted Hailes

Maxwell Air Force Base, Alabama

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Preface

Making the right decision at the right time is the essence of command. The genesis of this project lays in my conviction that technology may be outpacing the ability of military commanders to make the right decision. While this work only scratches the surface, my hope is that it will stimulate senior thinkers to insure the military, especially the Air Force, takes a decision-centered approach when fielding technologies to support the command and control process.

For this project, I owe considerable thanks to a number of people. First, Dr. William Martel and Col(ret) Ted Hailes provided absolutely critical guidance and support. While not an exhaustive effort, my research did take me to Air Force Laboratories at Rome, NY; Wright Pattererson AFB, OH; and Brooks AFB, TX in addition to Klein Associates near Dayton, OH. My thanks to several generous professiaonal for their time and assistance. I especially appreciate Dr. Gary Klein and his associates; Lt Col Frank Hoke from Rome, NY; Dr. Mike McNeese from the Human Engineering Division at Wright-Patterson; Dr. Samuel G. Schiflett and Dr. Linda R. Elliot from the Crew Systems Directorate at Brooks AFB; and Dr. Thomas J. Czerwinski from the National War College. Finally, my fellow Air War College students provided countless hours of debate on the "expanding field of knowledge and capabilities" all in the name of building future decision makers, thank you.

Abstract

The military is locked in a technology-driven orientation that designed great command and control systems for the cold war, but this same mentality is inadequate to address decision making challenges of the future. Consequently, the military must rebuild its intellectual framework to link decision makers to forces in an incredibly dynamic environment. The appropriate rebuilding is through a decision-centered approach to command and control systems. To adequately comprehend this approach, policy makers must understand how humans decide and how decision makers fit into complex systems.

This study investigates current research on decision making and links naturalistic decision making theory with complexity theory to provide a basis for analyzing decision support systems. Using Boyd's "OODA" loop as a frame of reference, this paper describes how the post cold war orientation has changed decision requirements. Next, the study proceeds with a discussion on decision theory with thoughts on how recent progress in naturalistic decision making theory should fundamentally redirect decision system design. Complexity theory offers an opportunity to link the decision maker to other elements of a unit and provides a basis for advocating decision-centered methods to improve decision performance. The study concludes with comments and recommendations on current efforts to move toward decision centered design.

Chapter 1

Introduction

"…the most profound implication of the new era often goes unremarked: namely, that the basic rationale for defense planning has shifted from threat to capability and from liability to opportunity."

–Admiral William A. Owens, Vice Chairman, Joint Chiefs of Staff

Fifty years from now, military historians will likely judge this last decade of the millennium as an era of tectonic change. Today, theorists explaining the rapid change often point to "revolutions" taking place. For the military, some say a "Revolution in Military Affairs" (RMA) is underway. Indeed, General Fogleman, former Chief of Staff of the United States Air Force, cites three revolutions: an information revolution, an international relations revolution, and an RMA.[1] All these "revolutions" demonstrate that major changes are forever modifying the way we communicate and the way we expect to fight wars. Clearly, the world has become an extremely complex environment, made up of multiple systems interacting in numerous ways.

To deal with this emerging complexity, the US military services have embarked on various studies and initiatives. The US Marines' *Sea Dragon,* US Army's *Force 21,* and the US Air Force's *New World Vistas* and *Air Force 2025* all seek to define some future world and shape the warfighting force required to fight in this future world. Linked to these efforts, the services have emerged with grand "vision" documents pointing the way

into the new millennium. For the Air Force, *Global Engagement: A Vision for the 21st Century Air Force* serves as the guiding light establishing core competencies and carefully linking them to the prevailing beacon for all services, *Joint Vision 2010* (JV 2010). Central to the development of all "vision documents" are arguments on force structure and the role of information technology.

One critical subset of every vision document regards command and control. Command and control has emerged as a key process, or subset of multiple processes, that addresses how commanders seize advances in technology to revolutionize how they make decisions and orient their troops in peace and in war. As the "new world" of command and control continues to emerge, technologists promise more information, and quicker ways to decide. Implied in these promises, is an increase in knowledge and less uncertainty which will provide an unprecedented orientation on the battlefield as commanders gain "total battlespace awareness." [2]

A New Orientation

The seduction of technology for the military, especially in the command and control field, is a promise that military forces will somehow become more lethal, more accurate, more efficient. For decision making, technology applications attempt to either "replace" the human or to provide tools for assisting the decision maker. The major advances over the past few decades have been in computer assistance where systems have "incorporated decision analysis, expert knowledge, and/or mathematical optimization."[3] Unfortunately, problems arise as decision makers attempt to apply these technologies in the real world for a variety of dynamic reasons. As the military shifts from "threat to capability and from liability to opportunity," there is an inevitable collision with the reality that

technologies tend to be bounded for linear applications while most real world situations have changing goals, shifting priorities, emergent properties and time sensitivities. In other words, borrowing from Van Creveld, the logic of technology is linear while the logic of decision making is nonlinear.[4]

This apparent paradox leads to great friction at the seam between technology and decision making. Every decision is unique and every situation offers a different orientation. Yet, the tools presented for the decision-maker's application must somehow be adequate to address the tailored, specific need. The challenge is to provide the right orientation by overcoming any mismatch between the linearity of decision making tools and the nonlinearity of decision makers. Thus, the revolution in technology has provided only one half a revolution in orientation. To complete the revolution the military should shift to a decision centered approach to system design, but must first overcome some remaining cold war mental restrictions.

The US military, especially the Air Force, is locked in a technology-driven orientation that designed great command and control systems for the cold war, but this same mentality is inadequate to address the decision making challenges of JV 2010.[5] Technology did not prevent, nor cause, the *USS Vincennes* to shoot down an Iranian Airbus in 1989. Nor did technology cause US Air Force F-15s to shoot down Army Blackhawk helicopters over northern Iraq in 1994. These incidents occurred, in part, because decision-support systems were inadequate for the task at hand. The systems were designed in the cold war to fight the "Red Army," but failed to properly orient decision makers to adequately deal with real world situations that more closely resemble future operating environments. These systems were "technology-centered," designed to

display information by taking advantage of the most up to date technology. They were not "decision-centered" systems, designed to provide decision makers with information sufficient to meet decision requirements. As such, the *USS Vincennes* incidents will continue and Air Force fighters may again shoot down Army Blackhawks until we develop systems with a decision-centered approach.

In his widely read article, *The Emerging System of Systems*, Admiral Owens said that the military must, "rebuild an intellectual framework that links our forces to our policy—no small task in a revolutionary era."[6] Likewise, the military must rebuild our intellectual framework to link the decision-maker to operational forces in an incredibly dynamic environment. The appropriate rebuilding is through a decision-centered approach to command and control systems. To adequately comprehend this approach, policy makers must understand how humans decide and how decision makers fit into complex systems.

The challenge before the military is great. To succeed in accomplishing JV2010's vision of fighting in the future, the services must immediately begin to take a decision-centered approach throughout command and control systems. Using Boyd's "OODA" loop as a frame of reference, this paper attempts to nudge readers toward a decision-centered approach by describing how post cold war orientation has changed decision requirements.[7] Next, the study proceeds with a discussion on decision-making theory with thoughts on how recent progress in naturalistic decision making theory should fundamentally redirect the military's approach to designing decision-support systems. Linking the decision maker to fighting forces is an extremely complicated process. The current tendency is to simplify this relationship and ignore the nonlinearity of the command and control process. Complexity theory offers an opportunity to link the

decision maker to other elements of a unit without overlooking nonlinear impact. The section on complexity introduces this science and provides a brief study on applying it to command and control in order to demonstrate how the decision maker fits into the system. A knowledge of complexity theory and decision making then provides a basis for advocating decision-centered methods to improve decision performance. The conclusion outlines specific actions to take to complete the revolution in orientation.

Notes

1 Daniel Goure and Christopher M. Szara, ed. Air and Space Power in the New Millennium. Washington, D.C.: The Center for Strategic and International Studies, 1997, introduction.

[2] JV 2010 demands delivery of these promises stating, "New technologies will allow increased capability at lower echelons to control more lethal forces over larger areas thus leveraging the skills and initiative of individuals and small units. These capabilities could empower a degree of independent maneuver, planning and coordination at lower echelons, which were normally exercised by more senior commanders in the past. Concurrently, commanders at higher echelons will use these technologies to reduce the friction of war and to apply precise centralized control when and where appropriate."

[3] Marvin S. Cohen, "The Bottom Line: Naturalistic Decision Aiding," in Gary A.l Klein, Judith Orasanu, Roberta Calderwood, and Caroline E. Zsambok, eds. *Decision Making In Action: Models and Methods.* Norwood, NJ: Ablex Publishing, 1993, p-265.

[4] Martin L Van Creveld. *Technology and war: from 2000 B.C. to the Present.* New York: Free Press, 1989, conclusion.

[5] In this paper the word "system" expresses an assembly of humans and machines forged together as elements of a process with the purpose to direct (command) military forces.

[6] Adm William A. Owens, "The Emerging System of Systems." US Naval Institute *Proceedings,* May 1995, 35-39.

[7] OODA-Observe, Orient, Decide, Act. See Chapter 2 for a description.

Chapter 2

Observe Orient Decide Act (OODA)

The roots of current decision making systems are planted in cold war thinking which developed momentum toward building "high tech" solutions to problems. Now, as the military struggles to transition to a fast-paced, dynamic age requiring "information dominance," the systems are inadequate because they are not designed around the decision, but instead are derivatives of an old momentum focused on a single fixed enemy. The following discussion describes the OODA loop as a frame of reference and provides a description of how the US military has struggled to move from a monolithic fixation to a capability-based system.

While there are various models for the command and control process, one description emerging toward the end of the cold war was John Boyd's "OODA" loop.[1] In recent years Boyd's OODA loop carved a niche in military circles as a common way to articulate the process a decision maker (or system) must flow through to gain an advantage over the enemy. Figure 1 shows the simple

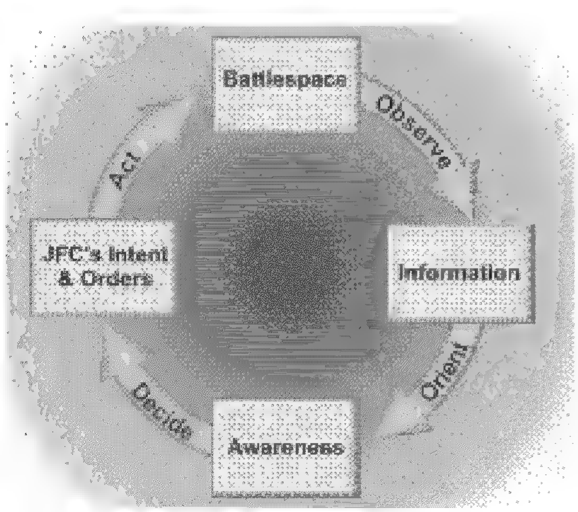

Figure 1. OODA Loop

version of the OODA Loop, as described in *Concept for Future Joint Operations* the Joint Publication directing the implementation of JV 2010. Boyd's thinking has had widespread exposure in military intellectual circles including use by the Joint Staff. Additionally, the United States Marine Corps has published the OODA loop in their doctrine as the way they believe the command and control process works.[2]

Boyd used the OODA loop to describe how to "get inside the enemy's decision cycle." The essence of the OODA process is that the decision maker must first observe the "battlespace." After observing, the decision maker analyzes and processes information to *orient* on the enemy. One way of doing this is to develop courses of action for possible future activity. At some point, the decision maker *decides* on a course of action. This decision is the point at which the commander or decision maker commits to a particular direction. Following the decision, the decision maker or the system he/she directs executes the course of action. Boyd referred to this stage as *act*, which is immediately followed by further observation in a continuing series of loops.

The OODA process repeats in a series of evolutionary moves intended to bring about an advantage over the enemy. Boyd taught that the person or force capable of moving more rapidly though a series of these loops would eventually "get inside the enemy's decision loop" and cause the enemy to constantly react, thus leading to eventual defeat. He emphasized that orientation drives the rest of the process to a great degree. It is in this phase of the OODA loop that the commander, or his staff, goes through a series of steps to analyze and synthesize information to determine how to orient on the enemy. Essentially, orientation drives decisions. Orientation is the step in the process where the decision maker builds situation awareness in order to comprehend the battlespace.

Cold War

The OODA loop can serve as a tool to help contrast cold war success with future operational requirements. For example, during the cold war the United States spent billions of dollars developing systems to "observe" the Soviet threat. Observation platforms included satellites, listening devices, early warning radar, and so forth. Essentially, the entire intelligence system was aimed at observing the Soviets in almost every imaginable way. Also during the cold war, the United States spent billions of dollars on the execution (*act*) phase of the OODA loop. Missile systems, bombers, submarines, fighters, nuclear aircraft carriers, and armor divisions were all designed to deter nuclear warfare and/or the midnight attack through the "Fulda Gap." The middle of the OODA loop during the cold war was relatively fixed. Our orientation throughout the cold war was clearly on the massive Soviet threat. Even though the US didn't really believe we'd get into a nuclear war, we clearly could not afford to miscalculate. So, the US military oriented on a massive missile threat and a huge conventional threat in Eastern Europe. This fixed orientation drove to relatively static decisions. Because of the threat of a missile war and the extreme time compression in the unlikely event that the US did come under a nuclear missile attack, we developed detailed "canned" decisions. Even the Fulda Gap scenario had preplanned fighting positions, targets, timelines, and so forth.[3]

From the perspective of the OODA loop, during the forty-year cold war the military didn't have to worry about developing dynamic decision systems. They essentially developed command and control systems designed for fixed "known" possibilities of the cold war. This made things simple in many ways and the military structure grew to

depend on incremental technological improvements to develop, refine, and improve command and control systems. Consequently, when the cold war ended, the US military had a command and control structure steeped in a full generation of superpower vs. superpower confrontation. The possibility of war on a global scale that could destroy humankind demanded a systematic, analytical approach that diminished any mistakes. This analytical approach was linear, meaning that staffs could take a reductionist approach to decision making by reducing a system down to basic components, applying a series of tests to the components, then put the system back together again and make a prediction about the way the system would react.[4] The US military knew who the enemy was and remained relatively certain about the enemy's intentions. So, technology-driven systems developed a series of indicators that, on any given day, defined the "state" and "intentions" of the enemy. This approach produced a very effective, yet rigid system, that contributed ultimately to the peaceful resolution of the cold war.

New World

Thus, when the cold war ended in 1991, the US military inherited an elaborate system for *observing* and for *acting* based on a fixed *orientation* and a rigid *decision* process. Today, for example, the military has a very robust ability to *act* based on the global attack and power projection capability built up originally to defeat the Soviet threat. The same effort yielded a robust capability to *observe* with collection platforms such as satellites, JSTARS, and AWACS. Beyond the technical capabilities, the military forces also inherited over forty years of momentum toward fixed positions with very little experience actually considering command and control systems for flexible options. For example, the deliberate planning process spent millions of man-hours refining plans to

meet specific threats. Then, when the Berlin Wall fell, the joint planning system went through major turmoil in a struggle to move from a massive fixed enemy, to adaptive planning based on unknown threats.

Towards the end of the cold war, the US military began to see inadequacies in its command and control decision making systems, especially when faced with "unusual" situations. The *USS Vincennes* and the AWACS/F-15 illustrations mentioned earlier are both tragic symptoms of a much broader problem. In each of these cases, decision systems failed because the information presented to the key decision makers failed to provide a basis to properly orient them on the problem at hand.

These decision system failures should not be surprising. Studies show that most decision aids fail to provide adequate support to the decision maker and are thus frequently discounted (even if they are providing accurate information).[5] Indeed, a recent NATO Research Group Study shows that most decision systems fail to develop the proper context for accurate decisions. So, while technology provides more information, it doesn't necessarily help the decision maker. Additionally, increased speed and processing of information may do more than just speed up the flow of data. This increased flow may fundamentally reshape the role of the human inside the decision making process. Cognitive psychologists are just now beginning to understand the consequences of this possibility.[6] The central cause then with decision system failures may be that the cold war decision systems actually lag behind the impact of new technology.

None of this is meant to imply that the systems intact at the end of the cold war were "worthless." As the Desert Storm performance demonstrated, these systems can "do the

job." Still, Desert Storm was a unique situation, and it is highly unlikely that any future enemy will prove quite as accommodating as Saddam. More often what military leadership has found since the cold war is that decisions are not "fixed or canned." There are many possible scenarios with numerous solutions to every problem. While the cold war allowed the luxury of assuming a "fixed" set of decision solutions, the post cold war world moving to the world envisioned by JV 2010 will not. The current tendency is to move technology from "observation platforms" to make them more flexible and provide better opportunity to orient on potential enemies. This "flexible" use of technology appears revolutionary, but falls short of meeting decision-centered requirements. Because of this, the military must destroy the old intellectual frame-work and replace it with an emergent perspective. Therefore, the military must move beyond fixed orientation on "proof" solution sets. The first step in this process of rebuilding the intellectual framework is to understand how humans actually decide.

Notes

1 John R. Boyd, "A Discourse on Winning and Losing." August 1987. A collection of unpublished briefings and essays. Air University Library, Document No. M-U 43947. This discussion is all from his work. Unfortunately, Boyd passed away in the spring of 1997 having never published his works. While many applaud his intellectual proweres and his tenacity in pioneering thoughts that are now captivating those interested in military applications of complexity theory, it is unfortunate that he never offered up his views to open academic criticism.

2 See Department of the Navy (1996, October). Command and Control, United States Marine Corps MCDP 6.

3 Obviously there are examples of confrontation beyond US vs. Soviet such as Vietnam and Korea. Still, these conflicts, like many others, were shaped and confined by the existance of the massive nuclear threats.

4 Reductionism, as used in this paper, is dividing up systems into comparatively simple pieces to study with mathematical precision.

5 Essens,, et al. Code – A Framework for Cognitive Analysis, Design, and Evaluation. Technical Report AC/243 (Panel 8) TR/17. Elvoir, VA: Defense Technical Information Center, 23 January 1995, xiii.

6 Randall D. Whitaker and Gilbert G. Kuperman,. Cognitive Engineering for Information Dominance: A Human Factors Perspective. Technical Report AL/CF-TR-1996-0159, prepared for United States Air Force Armstrong Laboratory, Wright-Patterson AFB, OH.

Chapter 3

Decision Making

An organization's view of how to make decisions shapes the design of decision systems. Generally, the military thinks of the decision-making process as a series of specific steps: establish some goal, gather and process information, go through a series of evaluations, then select a course of action.[1] These steps are a bit simplistic and our understanding of decision making has progressed significantly since the cold war started. Indeed, research in the past two decades has worked to distinguish between two distinct ways of making decisions, analytical methods and recognition methods, referred to below as naturalistic decision making (NDM).[2] Following is a description of these two approaches to decision making with an explanation for why the emerging knowledge of naturalistic methods should fundamentally change decision support systems.

Background on Analytical Decision Making

The foundation upon which the military built today's decision making systems is Newtonian Science. This methodology rests on a reductionist philosophy, which asserts that systems can be isolated, then reduced to basic components for further studying. For decision making, this means breaking down any problem into its basic elements, then studying these elements through some analytical process. The analytical study drives predictions that presumably transfer to the larger problem, thus allowing decision makers

to arrive at a reasonable decision. Reductionism assumes that performance of individual components will indicate how systems as a whole perform. This is known as linearity, in which the whole is proportional to the sum of the parts. Those who take a Newtonian view toward decision making, essentially assert that people make decisions as described previously. As a review, the steps are, select a goal, break the problem down into small components and carefully gather as much information as possible on the issue while developing courses of action. The last step is to evaluate all the data in a comprehensive way finally generating an empirical result pointing to the best course of action.

The military, as much as any other institution, derived benefits from a Newtonian approach to problem solving. During the industrial era, the battlefield rapidly expanded confounding commanders who sought to impose their will on the enemy. As the size of armies grew, the battlefield expanded physically and commanders lost the ability to "comprehend" the "battlespace." So, they developed staff systems to gather and synthesize information which they then attempted to internalize to make better decisions. In some cases commanders achieved success. The Prussian General Staff, for example, studied logistics and rail systems to determine the best way to rapidly mobilize for war and they were initially very successful during World War I. Of course, the first world war also offers many examples of the inability of commanders to deal with the changing battlefield, most notably when they failed to comprehend the preeminent nature of the machine gun and trenches in the defense, thus wasting million of lives over a few yards of terrain. As the world's militaries pressed beyond the horror of World War I, the application of Newtonian problem solving produced advances in technology which carried the military through World War II and into the cold war "missile age." Now, as

the military moves from the cold war to the information age, the analytical approach is still considered by many to be the best way to make decisions.

The analytical method suggests that decision makers take a systematic approach to gathering and analyzing data to eventually arrive at a "best possible" solution to a problem. Seeking the best possible solution explains why the US used it so well in the cold war. This approach seeks to develop values for "weighted" attributes and then identify the best possible alternative among those available.[3]

This analytical method should be familiar to many military people since it is the staffing method taught by most military organizations. For example, one analytical method, the model of concurrent option comparison, requires the decision making organization to gather extensive data, develop criteria to analyze that data, assign weights to the criteria, then weigh possible options systematically against the criteria to generate a tabulated score which will eventually lead the decision maker to the "best" solution or option.[4] To illustrate, when Iraq invaded Kuwait US Central Command studied several "avenues of approach:" up the middle, invade from the sea, left hook, and air campaign only, among others, before settling on a best course of action. A cold war example that worked very well is the Single Integrated Operations Plan (SIOP) which was a comprehensive analytical decision support tool that took a long time to develop, but that consistently produced an efficient analysis of how to strike strategic targets.

Theoretically, there are many advantages to using the analytical method. For example, this method drives the decision maker to gather the universe of knowledge regarding the problem. Also, the analytical approach is methodical, millions of man hours were expended studying photographs to develop proper target lists for the SIOP,

for example. Using an analytical approach, the decision maker fully develops all information and deliberately uses it for planning the best solution. Additionally, this approach is systematic, the staff or decision maker considers each plausible course of action carefully comparing each weighted factor one at a time. Finally, this approach seeks to optimize. That is, it is the method of choice for determining the best solution.[5]

There are several other characteristics of the analytical approach. First, it is time consuming to gather, process and analyze data (the SIOP took over six months to update). Also, this approach requires or assumes a high degree of accuracy and certainty of information--the data must be right to produce good analysis. Additionally, the analytical approach does not require a great deal of experience or judgment in the decision maker since the quantitative methods produce optimum solutions. Analytical skills, of course, are critical. In short, the analytical approach to decision making is linear, suitable to situations where time is not a major factor and where great amounts of accurate data can be processed.[6]

The qualitative nature of analytical decision making is appealing to the generation raised on "metrics" and provides concrete comparisons to grasp when trying to justify a particular decision. Consequently, as technology pushes computers onto desktops, decision makers have been naturally drawn to an illusion that they'd make better decisions because they have more information, faster.

Unfortunately, the promise of better decisions through technology is an illusion because the analytical approach is good in theory, but often falls short of the mark in practice. For example, when time compression becomes a factor, the analytical process becomes detrimental because it takes too long. Even if time is not an issue, the amount

of effort and resources required by the analytical process often leads decision makers to discount them, especially when rapidly changing conditions exist. Also, the analytical method depends on weighted factors and selecting the "weighted" values by itself becomes a type of decision. The problem with the assessment of values is they are often intuitive and introduce biases into the decision process.[7] Another shortfall with the analytical approach is decision training has not been able to produce adequate transferable results to the field. This is likely due to the fact that each individual decision maker draws from a different set of requirements based on his or her own experiences. Therefore, one specific problem solving method does not work for any two people given the same situation. Another practical issue is that a particular described method for making an analytical decision may not fit the circumstances the decision maker is facing. This forces the decision maker to go with "gut feel," which, is by definition intuitive.[8] These are just some of the practical problems associated with the analytical approach.

The biggest and most practical problem with reliance on the analytical approach is that experienced decision makers rarely use this approach. In the cold war, the US military understandably developed decision aides to support the linearity of the analytical process. Computers produced weighted values; displays listed timelines, aircraft status report, stock levels; and AWACS aircraft provided "real time" pictures of the airbattle, to name a few. Sometimes these aides were used, but often the data was ignored. Studies show that decision makers find ways to make decisions that circumvented the analytical decision aides, arguing that their expertise or gut feel led them to know that something was not quite right with the analysis. In fact, in over 90 percent of their decisions,

experienced decision makers use a different method all together. The method they actually use is an intuitive or naturalistic method.[9]

Naturalistic Decision Making[10]

Instead of being analytical, decision makers tend to be much more intuitive, and they evolve in the methods they use to apply their knowledge as they mature in their abilities.[11] Indeed, the type of decision people make is actually a function of several factors: time, environment (matter, space, energy, information), and emotions. Furthermore, the rate of change of the environment seems to drive decision makers away from analytical methods to more intuitive methods. One way to visualize this is to think of decision making as a continuum with analytical on one end and intuitive on the other. When change is slow, people tend to mix analytical and intuitive methods depending on the criticality of the decision and their expertise. As the rate of change increases, people become more intuitive, developing mental pictures and selecting solutions that satisfy conditions, then quickly moving on to the next problem. Thus, recent observations have confirmed that the type of decision people make is proportional to the rate of change of the environment. This reality, and the quest to understand its implications, has developed into studies of naturalistic decision making.

Naturalistic methods for decision making are different than the analytical approach in many ways. Naturalistic models suggest that decision makers work proficiently under time pressure by relying on their expertise to quickly and accurately build a mental image of the situation. The modern military calls this rapid battlespace awareness. Rather than processing large amounts of data to generate and compare several options, experienced decision makers use their knowledge and experience to develop a comprehension of

problem situations. They then make a decision based on this comprehension, or select a course of action they think will work and begin to run mental simulations to either validate or reject that proposed course of action. The naturalistic method does not necessarily seek the "best" course of action, especially as the rate of change of the environment increases. Instead, studies show that experienced decision makers, especially under time constraints, select the first course of action that will satisfy the conditions of the problem. This is called satisficing, as opposed to the optimized solution sought using analytical methods.

While experts differ on some details of NDM, there are many common themes. First, in real world situations, decisions are made in a variety of ways depending on the situation and the experiences of the decision maker. Next, while the methods for reaching the decision may differ, all require good situation awareness as critical to achieving a successful decision. To gain situation awareness, many decision makers often use mental imagery to visualize a problem and a proposed course of action. Consequently, experienced decision makers constantly strive to understand the *context* or the environment within which the problem is evolving. Binding these commonalities together is the observation that decision making is dynamic. That is, decision makers cannot isolate a problem from the environment as a separate process. On the contrary, successful decision makers possess the ability to see a problem and a decision as integral parts of a continuos process, like the OODA loop, an interaction between agents in a complex dynamic system.[12] A prerequisite to visualizing this on-going process is proper situation assessment.

Even though situation assessment is critical to decision making, in many "failed" cases, improper assessment led to bad decisions with disastrous results. The *USS Vincennes* shootdown of the Iranian Airbus is a prime example of a command and control system making an improper assessment then, forced by time compression to continue down the path towards disaster.[13] Another example is the AWACS/F-15 interface that led to the US Air Force destruction of US Army Blackhawk helicopters. Since situation assessment is critical to the decision process, understanding how decision makers image may help analyze the tools available to improve the decision making process.

Decision makers possess basically three ways to visualize or image problems. First, they see things how they ought to be in terms of their beliefs and values. Next, they visualize things in term of the goals and objectives they are trying to achieve. Finally, decision makers image the plan, or path, they are considering taking to reach their goals. The actual decision can take one or two paths with respect to the images. The decision maker can either accept or reject a specific goal or plan in a definitive decision. The other option is to take a more progressive approach where the decision maker decides to start down a particular path toward a goal, but also continually updates images while monitoring progress towards the goal.[14]

Since decisions are intuitive, based on assessment and mental simulation of the situation, aiding this process suggests interfacing with decision makers in a flexible manner. It follows that any interface should allow for the level of expertise, present information in an appropriate manner to develop a true grasp of the situation, and should recognize the interactive influence between the decision maker and the rest of the system. Allowing for the required expertise means understanding decision requirements in order

to set appropriate standards and to train people to that standard. Only then will we provide information in an appropriate manner that adequately orients the decision maker.

To summarize, while current decision support systems are based on an assumption of analytical decision making, most decision makers are actually intuitive. The essence of NDM is that decision makers operate based on their experiences and their perception of the situation. This has major implications for designing systems from a decision-centered approach in which information is focused to capitalizing on experiences while building true "battlespace awareness." Moving beyond information though, decision making also depends on the interactive influence between the decision maker and the rest of the system. This interaction has been difficult to conceptualize until recently, because theories have not incorporated the nonlinearity of decision makers. Complexity theory may provide this conceptualization.

Notes

[1] Lt Col George E. Rector Jr., "Leadership and Decision making." *Marine Corps Gazette,* October 1995, p-21).

[2] While there are varying opinions on how to articulate the two approaches, analytical and recognition methods represents the majority of views; see Klein, Gary A. "Strategies of Decision Making." *Military Review,* May 1989, 56-64.

[3] MCDP 6, p-101.

[4] Klein, "Strategies..," p-56.

[5] Schmitt, Major John F. "How We Decide." *Marine Corps Gazette,* October, 1995, p-16.

[6] Ibid.

[7] Marvin S. Cohen, "Three Paradigms for Viewing Decision Biases" in Klein, et al, *Decision Making...,*, p-46.

[8] Lee Roy Beach and Raanan Lipshitz, "Why Classical Decision Theory Is an Inappropriate Standard for Evaluating and Aiding Most Human Decision Making," in Klein, et al, *Decision Making...,* p-35.

[9] Notes from interview with Klein and Ass.

[10] Except where noted, this information is a synthesis of two key texts: *Naturalistic Decision Making*, edited by Caroline E. Zsambok, and Gary A. Klein, and *Decision Making...,* Gary A Klein, et al..

[11] Barbara Means, Eduardo Salas, Beth Crandall, and T. Owen Jacobs, "Training Decision Makers for the Real World," in Klein, et al, *Decision Making...,* p-326.

[12] Raanan Lipshitz, "Converging Themes in the Study of Decision Making in Realistic Settings," in Klein, et al, *Decision Making...,* p-137.

[13] Richard Saltus, "A Tragic Error Led to New Insights on Behavior in Crises." *The Boston Globe,* Monday, 23 February 1994, 25-27.

[14] Lee Roy Beach, "Image Theory: Personal and Organizational Decisions," in Klein, et al, *Decision Making...,* p-156.

Chapter 4

Complexity[1]

Designing systems that produce good decisions goes beyond a basic understanding of how we decide. We must also have a firm grasp of how the decision-maker "fits" with the rest of the system. During the cold war, with a "fixed" orientation, this was not as complicated because the military faced fewer variables, i.e., deliberate plans, and well-exercised scenarios. Now, scenarios change fairly quickly and are very different. Each Joint Task Force, for example, builds a new command and control structure unique for their particular operation. This rapid change will become even more important as the information age drives to distributed systems where various key players in a decision process are separated by oceans, but linked through space satellites. Indeed, JV 2010 demands command and control networks capable of operating autonomously or as fully integrated elements of a joint warfighting team in a highly dynamic environment. To build systems capable of meeting these demands, the military needs a theory that helps analyze the "nonlinearity" of our decision-making systems.

Complexity is a new science that provides the military a baisis to analyze the systems in which they must operate. The theory fits particularly well with command and control because of the multiple permutations encountered operating large, complex systems in a dynamic, time-sensitive world. Complexity is germane to the topic at hand

because it helps answer the question, "where and how does the decision maker fit in?" The following discussion gives some examples of how people operate within complex systems, followed by a basic discussion of complexity theory and definitions. Finally, these definitions applied in a context of complex systems demonstrate how to improve design of decision systems.

A recent Air Force experience with the AWACS system helps put this problem in perspective. Recently, the Air Force, in an effort to save money through personnel cuts, made changes to the AWACS Senior Weapons Director (SWD) position. For personnel reasons, the Air Force elected to change the requirements of the SWD from an officer position to an enlisted position. This move has had very negative consequences for a variety of reasons. Most importantly for this paper, personal testimony and observations in test situations show that these enlisted SWD are much more reluctant to make decisions than officers were.[2] In practical terms, this means SWDs pass some critical decisions off to either the fighter pilot they are directing, or back to a controlling ground facility. Obviously, this passing of decisions from one "key node" to another can have serious consequences, especially if the other nodes are already "task saturated." The resultant affect is nonlinear in a negative way, a "minor" change in manning a key decision node has dynamic effects on the entire system.

While the reasons for a reluctance to make decisions varies depending on the experience of the enlisted member, one overarching reason deals with the enlisted director's approach toward decision making from a totally different context than the officer's. In retrospect, the personnel decision was made without considering the unintended consequences this would have on other members of the air defense system.

The behavior of the system changed as a result of a personnel decision made without considering the impact of the AWACS system on the rest of the command and control system. As long as an intentional effort was made to fundamentally move the AWACS away from the decision process, then the personnel decision is reasonable. If, however, the AWACS is still expected to make key decisions on how and when to engage hostile targets, then the personnel decision has introduced a significant shortfall into the system. Perhaps the decision was made, with good intentions, to capitalize on new technologies intended to transfer battlespace awareness to commanders at the cost of others. This may have been the case, but more likely the issue is an improper appreciation for how this specific node fits within the broader system of air defense. Developing this appreciation is particularly difficult with dynamic, high-tech systems such as AWACS.

How can organizations deal with a world that is so dynamic, so confusing, so eager to feed on one generation of technology or ideas only to reject that generation as soon as a newer, more promising enterprise emerges? Questions to answer these type of questions in recent decades led to complexity theory. Complexity theory seeks to explain how dynamic systems operate in a changing environment made up of nonlinear systems.[3] Nonlinear systems are those whose outputs are not proportional to the inputs. In effect, complexity seeks to understand and explain things that direct mathematics has been unable to explain. This theory stands in contrast to "cold war," reductionists who sought to take large complex problems and reduce them into their most basic form for an explanation that, in a linear world, would be applicable to the larger view. Just as the AWACS example describes, each action tends to produce both intended and unintended

consequences. These consequences often reverberate to produce both positive and negative aggregate behavior of the total system much different than anticipated.

Complex Systems & Organizations[4]

One way to think of an organization within which a decision-maker operates, is by visualizing a network with several different nodes and with lines connecting each node. With this mental image, consider one of these nodes as being the decision-maker and each of the other nodes as some important part of the command and control network. The lines connecting the nodes represent the various means of communication available to move data and information between the nodes. The actual movement of data and information along these lines can be referred to as "flows".

Now, considering this network as a model, a complex adaptive system is a system capable of gathering information, assessing the information and then prescribing a behavior to react to this information to produce an outcome.[5] Each step in this process has a consequence which is fed back to the system to cause a selection pressure on the various parts or elements of the organization. The result is a system that is constantly "deciding," constantly changing and constantly adapting to the environment and other systems within the environment. It is important to note that a complex adaptive system may contain other complex adaptive systems or may itself be a part of a system of systems causing some greater affect. The AWACS has several weapons directors on board working together to accomplish a purpose of "painting the sky." AWACS is a complex adaptive system and as an entity, fits into a larger air defense complex adaptive system.[6] The AWACS is one node in a much larger system which links JSTARS, air

defense operation centers, ground based radar, fighter aircraft, the JFACC, and other elements.

Complex adaptive systems are composed of parts or elements, called agents, that interact to constantly produce some effect. In the complex system, these on-going interactions always create a new environment, which has some affect on the individual elements and thus changes them. The consequence of this interaction is that once changed, the elements will again interact to produce again, this time in some slightly or radically different way. Consequently, the system as a whole is constantly changing as agents interact with each other to affect change.[7] The degree to which each element is dependent on each other will directly affect the propagation of change throughout the entire system. For example, when a weapons director on an AWACS, AGEIS, or ground facility identifies a hostile target, their perspective of the battlefield changes. Feeding this information to a pilot flying combat air patrol also changes the perspective of the pilot. These two agents working together hope to develop an emergent behavior that protects the friendly airspace, then the agents interact and change to create some affect.

This interaction between agents is an important concept to grasp in a quest to understand complex adaptive systems. As described above, interaction between agents causes the system itself to change. Affecting one agent in a system, affects every other agent coupled to the first agent, to one degree or another. Steve Rinaldi, in his paper *Beyond the Industrial Web,* summarizes interactions between agents as either tight or loose. Tight couplings between agents mean they are highly dependent on each other, while loose couplings imply the opposite.[8] The extension of this interaction is that any impact on an agent in a system changes the system as a whole through the reverberating

impacts. Tight couplings would result in more immediate impact than loose. To continue the AWACS example, the shift from officer to enlisted SWD has affected the AWACS crew as well as the greater air defense system because of degraded decisions.

By definition, agents grouped together constitute a system. These systems can then become agents themselves, called meta-agents, in some larger system.[9] Those meta agents, too, have the same properties and characteristics and relationships as the agents affecting the larger system. Meta-agents can also be grouped into a larger system that becomes meta-meta-agents. This great complex system of meta-meta-agents is another way to describe what Admiral Owen's refers to in his description of a "system of systems."[10]

Complexity Theory and Command & Control

Based on the basic theory of complex adaptive systems, we can begin to apply the terminology to the real world for analysis. Societies are complex adaptive systems. Military organizations, too, are complex systems. When the US introduces a military organization into another country, the nation is introducing a "meta-agent" into a larger system for the purpose of changing the environment of that larger system or for bringing about some specific change in behavior of the larger complex adaptive system. Bosnia may serve as a practical application.

The International Forces (IFOR) exist as an aggregation of international peacekeeping forces introduced into the former Yugoslav nation. This aggregation of agents is expected to "couple" with the fighting factions (other meta-agents) to form an emergent behavior of the system as a whole, peace. Certain agents in this meta-meta-system are tags, meaning that they create a certain identity toward which the other agents

migrate and aggregate. So, it is through these agents that the international systems seem to be seeking leverage points to encourage the "flows" that will lead to the desired emergent behavior. What is intuitively understood, but unanswered, is the question about exit strategy. Once the inserted meta agents (the IFOR) withdraw, will the remaining agents in the system be able to continue with the desired behavior, or will they adapt to the void by squaring off against each other in the traditional self destructive ways? By studying the couplings and flows in the complex adaptive system, the IFOR may be able to devise a strategy that creates a system capable of withstanding the withdrawal of peacekeeping forces. This is an example of how to apply complexity theory on a very large scale.

On a different scale, complexity theory provides a framework to study military organizations. Military organizations are complex adaptive systems made up of many agents, both human and machine, who form together in varying ways depending on the environment etc. Most military organizations have a rather formal hierarchical structure, which attempts to control and direct the flows through the system. The key formal or informal leaders in the military complex adaptive system are tags. Sometimes these tags are so powerful that they greatly affect the flows through the system. An example is when an organization is waiting to deploy, or start a training event, because the commander has not made a decision. The commander may have a good reason for delaying, but his/her inaction can affect the entire system in nonlinear ways. Agents in the military system are commonly "decision makers." They have the power to direct resources, which affects the flows through the system and often greatly influences the emergent behavior of the entire system. Obviously, the staff and advisors to the decision

making agent have a higher influence, thus a tighter coupling with the decision making agent than do others. Additionally, some advisors have more influence than others, this too means they have stronger couplings.

As the US accelerates into the information age, agents and the relationships between them come under intense study. Fiscal and time constraints often lead military thinkers to believe that a machine is a much better agent than a human in many cases. Still, any position demanding a complex cognitive task probably requires a human. Unfortunately, as engineers design and redesign systems, they consistently attempt to reduce the human requirements.[11] This may be counter productive if the reduction is done without a proper analysis of any impact on the command and control system.

From the human perspective, at least two key concepts emerge by applying complexity theory to command and control of high-tech organizations. First, people are the key part of the system because they are the adaptive agents. Second, complex organizations know that their people must excel at learning and innovation.[12] Decision makers are complex adaptive systems; they display emergent behavior and adapt. Additionally, decision making is a product of human thinking which is often nonlinear. Thus, system designers should consider these nonlinear affects as they change or design command and control systems.

Taking a decision-centered approach to designing decision systems, encourages the study of flows into key nodes and the emergent behavior of the system as a whole. If the decision behavior is inadequate, designers must look to the whole system to determine causes and impacts on decision requirements. This approach, analyzing how the decision maker fits into the system and designing the system around decision requirements, stands

in contrast to a technology-driven approach. The question shifts from, "what can I do with my technology" to, "what do I need my technology to do?"

Notes

[1] The lexicon of complexity is new, emerging and sometimes difficult to grasp. Still, this theory offers us an opportunity to analyze our dynamic systems in a manner that more closely predicts reality than our former, liner methodology. See Appendix for more technical definitions on complexity.

[2] Notes from interview with members of Armstrong Lab @ Brooks

[3] See Major Steven M. Rinaldi, *Beyond the Industrial Web: Economic Synergies and Targeting Methodologies.* Maxwell AFB, Ala.: Air University Press, 1995, p-7. And David S. Alberts, and Thomas J. Czerwinski, ed. *Complexity, Global Politics, and National Security.* Washington, D.C.: National Defense University, 1997, xiii.

[4] Most of the information in this section is derived from works of others. See bibliography for an extensive list. Recommended readings include titles written by, Hollandn(1995), Rinaldi (1995), Waldrop (1989), and Alberts & Czerwinski (1997).

[5] Murray Gell-Mann, "The Simple and the Complex" in *Complexity, Global Politics....,* p-9.

[6] Obviously, the term "team" often applies as we consider complex adaptive systems like the AWACS. While we are just now making progress in studying decision "teams", the importance of linking these concepts to complexity theory is to demonstrate how we may analyze each "node" in a system at its given level. Level referring to an individual, a distributed team, etc. The term "system" is more appropriate as we study command and control because it allows us to incorporate machines as nodes while the term "team" carries a more homogenous "human" connotation.

[7] James N. Rosenau, "Many Damn Things Simultaneously: Complexity Theory and World Affairs" in *Complexity, Global Politics...., p-83.*

[8] Rinaldi, p-8.

[9] John H. Holland, *Hidden Order: How Adaptation Builds Complexity.* Reading, Mass: Addison-Wesley Publishing Company, Inc., 1995, p-6.

[10] Owens.

[11] I will not directly address the inherent risks involved in this process, other than to point out that historically we have dealt with uncertainty by distributing it to subordinate commanders or other "agents" in the system. The literature on dealing with uncertainty is vast, but the essence of emerging thought is that we will never fully remove uncertainty. Indeed, increased information may actually greatly increase uncertainty. The implication of this is that replacing a human with a computer moves the uncertainty along to another human agent. System designs should consider the aggregation affect on key decision makers as they move this uncertainty along.

[12] Robert R. Maxfield, "Complexity and Organization Management" in *Complexity, Global Politics....,* p-183.

Chapter 5

Moving toward Decision Centered Approaches

The preceding chapters note that the military must complete a revolution in orientation by shifting momentum to develop command and control systems for more dynamic environments. While technology promises to accelerate the rate of information flow to the decision maker, focusing on this technology without the proper "compass" will fail to deliver the decision performance envisioned by JV 2010. Breaking through the cold war momentum requires a decision-centered approach to rebuild the intellectual framework that links the decision maker to operational forces. Naturalistic decision making provides the basis for rebuilding the intellectual framework by providing an understanding of the experienced decision maker's requirements. Additionally, complexity theory provides a framework for studying how the decision maker fits into the command and control system. The decision maker's fit in a system is one aspect of studying how the decision maker is linked to the "world he commands and controls." Another aspect of linking the decision maker is through decision making aids. Decision aids drive the decision maker's orientation and are where the real "promise" of technology lays. For example, Rome Laboratory is developing data walls and virtual reality displays with the potential of providing the commander a 360-degree view of the battlespace.[1] These tools are decision aids.

The world of JV 2010 requires and assumes a high degree of confidence and use of decision aides. Unfortunately, as pointed out earlier, most decision aides "fail to provide adequate support because of lack of knowledge concerning decision making activities in command and control."[2] Too often, decision support is thought of as jamming more information, faster, at the decision maker. In fact, more information may not help the decision maker, only useful information is helpful. Providing this information through useful aids requires decision-centered designs.

The goal of designing decision aids is to meet decision requirements. Identifying decision requirements should drive us to start with the key node, "decision maker" and ask, "is the aid in question designed to facilitate flows to and through this key node to enhance the decision?" This approach should result in considering at least two major categories. First, what are the barriers to flows into the decision node that may degrade decision making. Next, what guidelines can we apply to the decision aids to insure they meet the demands of the decision maker?

Klein conducted a study on information dominance and implications for decision makers.[3] His study produces six barriers to individual and team expertise which can limit the quality of "good decisions." These barriers are: excessive data, pre-processed data, excessive procedures, performing formal analyses, passive data handling, limited ability for information seeking and interfaces that obscure the big picture.

Looking at these six barriers through the spectacles of complexity, we can see the connection between the system supporting the decision maker and the tools provided to support his process. At least three basic components emerge; the primary agent (decision maker), the supporting agents (human or computer) and the coupling (connectivity)

between the two. Flows through these key nodes greatly affect any emergent behavior of the system. Consequently, engineers should consider each of these barriers as they design decision aids or command and control systems. Beyond considering these barriers though, engineers need to consider basic decision aid guidelines that will also greatly facilitate the design process.[4]

The NATO Research Group (NRG) recently published an example of decision aid guidelines. Following is a very brief summary of the guidelines and are presented here not as an exhaustive list of considerations, but as an example of the parameters we should consider as we move toward developing more effective decision aids.[5] First, the NRG guidelines indicate that decision aides should be decision centered, based on analysis of decision requirements, not "force-fit" using the latest technology available. Additionally, decision aid design should focus on what the aid is intended to do, not what it looks like. Also, scope is very important, especially when designing aides for command and control. This is a particularly vulnerable point because so many decision aids propose to handle all aspects of planning or information processing, which does not generally work. Finally, decision aides should avoid imposing "computer level of precision" on decision makers. As discussed earlier, humans are more holistic in their decision making, rigidity and exactness do not necessarily assist the decision making process. Considering these guidelines, along with the barriers mentioned earlier, will lead to developing a decision-centered approach which constructs systems capable of operating in a dynamic environment.

These studies are only two of many ongoing efforts to improve decision systems. The Air Force *New World Vistas* initiated a major effort to improve human centered

systems which, in part, support improved decision support structures. Still, indications from some of the military's larger command and control systems, are that they are developing "neat" technology without considering the actual decision tasks to be performed.[6] Indeed, many design engineers assert that as technology presses ahead, the military is better off to remove the human from the loop.[7] This thinking overlooks the nonlinearity of humans and the advantage gained through using this nonlinearity. Instead, we should consider the human as a key agent in the "system of systems." Success will come to those who tailor decision aids that support the flows and tags in the complex adaptive systems. These aids must also be flexible enough to adapt to specific situations and meet tailored awareness requirements.

Once again the AWACS example, illustrates immature decisions with respect to decision center design questions. Specifically, when the Air Force replaced the weapons director on the AWACS with senior enlisted personnel, the decision to train enlisted people for the position seemed feasible. The question is, did the Air Force take a decision centered approach when considering this move? The indications are that they did not. Informal interviews evaluating the performance of these new enlisted directors shows an inconsistency in the ability of enlisted directors to make mature decisions. This is not to make a value judgment on whether or not they are fully capable of making decisions. The observation of research psychologists is that the enlisted directors show a tendency to defer critical decisions to either the pilot of the fighter aircraft or to the controlling tactical command and control node. This is equivalent to moving the decision from one decision node to another decision node without considering the task loading of that particular node (for example, the pilot is often very near task saturation in a fight, to

move more to this individual may lead to decision failure). While the AWACS example is clearly at the tactical level, the mentality that allows these problems to take root can also exist at any level in the command and control process.

Taking a decision-centered approach can help prevent placing the system capability in front of the decision requirements. Fortunately, there are signs of a shifting tide. For example, several studies within the last three years support the concepts laid out in this paper.[8] The NATO Research Group Study on Decision Aids to Command and Control; Klein's study on AGEIS cruisers; Kuperman's Cognitive Engineering for Information Dominance; and Elliot's, A system to Enhance Team Decision-making Performance all move in the direction of decision-centered design to support cognitive tasks required in the next millennium.

Studies of AWACS distributed decision making and Naval Research Lab studies of Aegis cruiser activities should be capitalized upon. These initial efforts to grapple with decision-centered design are yielding lessons transferable to most command and control systems. The key is to consider the systems in light of JV2010: what complex adaptive systems does JV 2010 propose? What nodes require complex cognitive tasks? From this we can design the systems to support those nodes, and educate and train the humans required to make key decisions.

One major caution is to avoid a tendency wherein the "old momentum" absorbs the results of these studies. To prevent this, the Air Force would be wise to steal a page from the Navy "play book". In the summer of 1997, the Chief of Naval Operations directed Naval command & control to take a decision-centered approach. This approach included decision-centered: system design, aids and training. The Air Force is now on the right

path in some areas. In addition to the above named studies, the Air Force Lab director recently encouraged Armstrong Laboratories to engage with the Navy on a project that explores decision requirements from two person teams to very complex high-level organizations. Air Force leadership should encourage these efforts to move forward, unimpeded by the cold war momentum, resident in our bureaucratic structure. This requires a good understanding on how we decide, and a nonlinear approach to the entire command and control decision-making process.

What the Air Force lacks today is clear, unequivocal commitment from the top for a decision-centered approach. Also, education and training in the Air Force hasn't even begun to address decision-centered issues. While the Marines & Navy have fully embraced decision-centered methods, the Air Force professional military education doesn't mention it. In fact, in his article "Brilliant Warriors" published in, *Air Force 2025,* the commander of Air University discusses the expertise required of future Air Force Warriors, but fails to make any mention of new concepts in decision making. Clear directives from senior leaders should complete the revolution in orientation to gain a decision-centered advantage.[9]

Notes

[1] Notes from interviews at Rome.

[2] Essens, p-ix.

[3] Gary Klein., *Implications of the Naturalistic Decision Making Framework for Information Dominance*. Technical Report prepared under Prime Contract F41624-94-D-6000, Armstrong Laboratory, Human Engineering Division, Wright-Patterson AFB, OH.

[4] An Important note: decision making guidelines are different than human-computer interface guidelines. The latter has numerous sorces, but deciison-aiding guidelines are scarce. Essens, p-149.

[5] One important note, the NATO guidelines are derived from failed attempts to develop aides that actually work. The NRG study notes that most decision aids fail to perform adequately, but there is very little documentation on these failures for a variety of reasons.

6 Notes from visits to Air Force Labs.

[7] Ibid.

[8] See bibliography for extensive list

Notes

[9] Jay W. Kelly, Lt Gen. “Brillian Warrior” in *Air Force 2025, White Papers, Volume 1*, Maxwell AFB, AL: Air University Press, 1996, 239-250.

Chapter 6

Conclusion

Those who proclaim that technology is on the verge of removing uncertainty are quickly reminded of the *USS Vincennes* incident, the US Air Force F-15 shootdown of the two US Army Black Hawks and the graphic scenes of Somali warriors dragging the body of a U.S. Army soldier before the world on CNN. These incidents are examples of the persistent nature of uncertainty throughout the ages. Additionally, they seem to confirm the fear of traditionalists who point out that technology can provide lots of information, but not necessarily knowledge. Based on a knowledge of complex system characteristics and drawing from the discussion on decision making, we can see that decisions are affected by flows into the decision process and by what takes place inside the decision node itself. Military command and control will produce better decisions by improving flows (design of the system), decision aides (computers), and the actual decision maker (training and education).

Now is the time for the military, especially the Air Force, to shift fully into a decision-centered design approach. Many studies show that a decision-centered approach reduces long term costs, while actually decreasing total time required to mature a system's decisions in a manner that allows for better decisions. The NATO Defense Research Group Study suggests a taxonomy for designing decision-centered aides and

provides guidelines for developing decision aides based on previous decision aides failures. Complexity Theory provides the basis for studying the nonlinearity of decision making. Naturalistic Decision Making gives us new insight on how we decide and how to train our future decision makers

Interestingly, some still say that the commander of tomorrow will indeed have total battlespace comprehension as a result of a "system of systems." Is this a throw back to the Napoleonic era? When Napoleon fought, he was able to "comprehend" his battlespace and direct lower echelons with the timing and tempo that eventually led to the destruction of his opponents. In the hundred years following Napoleon, the industrial revolution hurled warfare into an era where the expansion of the battlefield made "total comprehension" and "command and control" virtually impossible for the operational commander. Staffs emerged to assist the commander in a quest to gain this much desired and elusive comprehension of the battlespace, but the fog and friction introduced by the vast expansion of the battlefield still persisted in denying the quest. If Admiral Owens is correct, we may have returned to the days of Napoleon, but only if the decision making systems can adequately support decision requirements. Complete the revolution!

Appendix: Complexity Definitions

Complex adaptive systems, are made up of agents interacting with each other and with the environment of the system. Complex adaptive system appear in many forms and have several varying characteristics. John Holland's *Hidden Order: How Adaptation Builds Complexity* stands as the latest and one of the most authoritative works on complexity theory. In his book, Holland lays out four properties and three mechanisms characteristic of complex adaptive system, understanding these is basic to understanding how complex adaptive system operate and provides us with a starting point for comprehending the complex world.[1]

Aggregation

Aggregation of complex adaptive systems is a key property. This is the property wherein the agents of a complex adaptive system combine to interact with each other and the environment of the system as a whole. This interaction on the whole produces an emergent behavior of the complex adaptive system, which is different from the summation of the efforts of the individual agents. Consequently, it is difficult to describe emergent behavior in terms of an individual agents. For example, in the military, we speak of a combined arms team, or a strike package. In each instance, the performance of the individual agent has an impact on each other. The emergent behavior of the total system interacting with the environment produces an outcome very different than if the individual agents act alone. Furthermore, either of these two examples, given the same actors, would never produce the exact same results on any two different days. The emergent behavior can rarely be duplicated in a complex adaptive system because of the constant changes.

Nonlinearity

The properties of systems that produce non-proportional results is nonlinearity. Nonlinearity means the whole is not necessarily equal to the sum of the parts. Nonlinear properties make the emergent behavior of the aggregate more complex than we can project from analyzing the individual parts. This non-proportionality makes efforts to predict cause and effect very difficult.

Flows

Flows are the property of the systems that allow/facilitate movement between agents. Flows are the actual movement through the nodes and connectors of a system. Nodes are the agents, the "processors." All complex adaptive system flows are time variant – they vary over time and expand/increase, appear/disappear depending on how well the agent adapts. Consequently, examining the flows can reveal constantly changing patterns that reflect the changes of the complex adaptive system over time. Two key properties of flows that Holland sites are the multiplier effect, which occurs when additional resources are injected at a given node, and the recycling effect, in the effects of cycles on the complex adaptive system (growing off already used resources internal to the system).

Diversity

Complex systems are aggregates of very diverse agents. The degree of diversity varies within the system. This property of the complex adaptive system may seem contrary to organizationally efficiency at first blush. Some assert that a grouping of generalists is the better way to approach efficiencies in a system. Interestingly it is the diversity within and among the agents that keep the complex adaptive system from stagnating. The agents are homogenous in their identify, either closely or loosely, with the overarching direction of the system, yet are extremely diverse inside the system with respect to each other.

Tagging

Complex systems contain tags as a selective property. Tags define the networking of a system by a form of "useful" interaction. Useful interactions between agents tend to form tags around the more productive agents or tags, while those that detract or don't contribute lose eventually cease to exist. An interesting thought for military organizations are the "informal" tags that develop to accomplish a mission. At times, these become more powerful and productive than the formal hierarchy.

Internal Models

Internal models provide the system with the ability to anticipate. Models allow the agents within a complex adaptive system to assimilate information in the form of a recognizable pattern, then develop this pattern into a predictable set of consequences. This modeling effort allows the system to predict the outcome of different course of action based on the pattern formed from the model.

Building blocks

In order to model, the agents within a complex adaptive system must be able to develop recognizable patterns. To do this, the agents draw upon building blocks of recognizable elements. From a human perspective, we observe complex scenes and select recognizable elements from the scene to serve as the basis of understanding. This allows us to encounter an event that we have never faced before and still deal with it based on the building blocks we posses.

Notes

[1] See Holland (1995). Except where specifically noted, all this material is a derivation of his work. Other works contain similar characteristics articulated in one form or another. To expand your basis, see Rinaldi (1995), Alberts & Czerwinski (1997), Pellegrini (1997), and Czerwinski, (draft).

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Air War College
Maxwell AFB, Al 36112